

COOLING TECHNOLOGY MANUAL



Chapter 13

INSPECTION OF COOLING TOWERS

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CTI Chapter 13 (13)

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This guideline document summarizes the best current state of knowledge regarding the specific subject. This document represents a consensus of those individual members who have reviewed this document, its scope and provisions. It is intended to aid all users or potential users of cooling towers.

Approved by the CTI Executive Board



This document has been reviewed and approved as part of CTI's Five Year Review Cycle. This document is again subject to review in 2018

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Inspection of Cooling Towers

Section 1. Scope

13.1 The equipment and materials in a cooling tower are subjected to a harsh environment and usually a less than ideal inspection program. This chapter deals with the cooling tower inspection format, associated equipment and material problems, and suggested inspection and maintenance procedures.

The “Cooling Tower Inspection Format” has been developed as an operational maintenance tool and record of general tower conditions. The inspection format is meant to be used in conjunction with tower manufacture’s operation and maintenance manuals. It utilizes CTI Publications such as Bulletin WMS-104 “Wood Maintenance,” for the analysis of types of deterioration found in cooling towers, as well as a standardized rating system for the degree of deterioration.

The frequency at which the inspections should be performed is dependent on the users individual preference based on operational or general maintenance criteria.

Normally each manufacturer will recommend inspection intervals based on past experience records. The inspection procedures used may vary from user to user. CTI Bulletin WMS-104 records three basic procedures and observation techniques for wood consisting of visual, strength, touch and probe. These methods can be augmented by additional technical sampling for water analysis, timber and component part cross section sampling, E modulus testing, etc.

Section 2. Definitions

13.2 For definitions of terms used in this chapter see Chapter 1 of the Cooling Tower Manual, “Cooling Tower Operations”.

Section 3. Pre-Inspection Safety Considerations

13.3 Prior to the start of the inspections, discussions should be held between plant forces, inspector(s), water treatment personnel, and any other party involved in the inspection site. The purpose of these discussions should be to address all of the hazards involved, and to determine how best to mitigate the risks associated with those hazards during the inspection.

A. Chemical Injection. It is common practice to disable the injection system for a sufficient time period to allow chemicals to reach safe levels. It may be advisable to determine whether the chemical concentrations in the circulating water exceed safe concentrations during normal operation. The MSDS Sheet should be consulted to determine safe concentration levels. If normal operating concentrations are within safe levels, consideration can be given to bypassing this step.

B. Personal Protective Equipment. Personal protective equipment (PPE) is typical at most all plants and facilities. Site specific requirements must be learned and adhered to prior to entry into plant and cooling tower. Typical PPE

include hard hat, safety glasses, harness, lanyard and hearing protection. Steel toed boots and fire retardant clothing (FRC) may also be a requirement.

C. Eye Protection. It is common practice for a plant owner to require eye protection in all operating and maintenance areas. This is in recognition of the hazards that projectiles and other foreign objects pose to the eyes. However, in an atmosphere such as that which is typically present within an operating cooling tower, there is an additional hazard present – the atmosphere is usually saturated sufficiently to fog the lenses of these safety glasses. Consideration should be given to the risk from the reduction of vision from this fogging effect.

D. Fall Protection. Fall protection is required by OSHA and local plant requirements. OSHA requires a tie off connection to be rated for 5,000 lbs or shall be designed as part of a complete fall arrest system which maintains a safety factor of 2.0. Several methods of fall protection are available, each with situations that make it the appropriate choice for use. Harnesses are limited by the availability of solid anchor points. Retractable lifelines may pose hazards if the person is pulled over sharp surfaces or over the structure typical inside of cooling towers. Each situation must be evaluated to determine the best method.

E. Lock Out/Tag Out. All rotating equipment and water distribution systems must be de-energized prior to entry.

F. Permits. Each plant’s procedure for confined space entry permitting and work permitting should be followed.

G. Biological Activity Protection. The primary biological agent known to present any risk to human health in a cooling tower system is *Legionella pneumophila*, commonly known as Legionnaires’ Disease. For further information on *Legionella pneumophila*, refer to the paper, “Legionellosis Guideline: Best Practices for Control of *Legionella*”, available at www.cti.org. Other biological risks should be evaluated on a case by case basis.

H. Site Specific Contamination Issues. Other issues may need to be addressed prior to the start of the inspection. This includes but is not limited to process contaminants, adjacent operating units or plant sites, or any other contaminant sources specific to the site.

Section 4. Inspection of Wood Members of Cooling Towers

13.4 Cells should be checked at regular intervals so that each cell in the complex is inspected at least once a year. Tower wood members are based on 50 years of service life; however factors such as service conditions and upkeep play a major role in a tower’s life expectancy. Additional inspections should be made after high winds, seismic events, chemical excursions, major mechanical events, etc. See also manufacturer’s recommendations.

Inspections should include the following observations:

A. Visual – The general appearance of the lumber and the depth to which loose or punky materials could be scraped off with a dull instrument. What to look for-

1. Chemical Surface Attack can be caused by a number of different chemicals. Excessive chlorinating is usually the chief offender; however, excessive concentrations of carbonate alkalinity in the tower circulating water for prolonged periods will also cause this attack. Chemical attack is observed as wood delignification due to the selective removal of lignin, which is the cellulose fiber-binding agent. It follows, then, that this attack is most prevalent in the flooded tower fill and areas frequently wetted with water, such as the structural members. Chemical attack is a thin-layer surface attack and can be detected and checked before serious damage occurs, provided periodic inspection are given the tower and corrective measures are taken when this type of attack is discovered. For additional information, see Bulletin WMS-104 “Wood Maintenance”.

2. Biological Surface Attack (or soft rot) is caused by fungi that selectively attack cellulose of very damp wood, leaving primarily lignin. This attack is characterized by a dark appearance and a brash condition of the wood surface. The wood surface becomes “punky” or checked. The active growth of the wood-destroying fungi is confined to the surface layers and remains superficial unless the wood is allowed to dry out frequently.

3. Biological Internal Attack occurs below the surface of the wood particularly around areas of exposed end grain (holes, cuts, etc.), and often goes undetected until the infection has spread widely, resulting in serious structural damage. The decay can be white rot, attacking both cellulose and lignin and leaving a spongy or stringy mass, or a brown rot, attacking primarily cellulose and leaving a brown cube like pattern. This type of attack is more apt to occur in the warm, moist, but non-flooded portions of the tower. Check for signs of “wood boring” insects that may be present beneath the normal water level in the cold water basin.

4. Iron Rot is a chemical attack caused by the formation of iron salts around corroding ferrous parts in contact with wood. The wood in the adjacent zone has a charred appearance and may also be more susceptible to fungal attack. Since connections are affected in many cases, extensive repairs may be required. See also Chapter 9 – “Materials of Construction for Cooling Towers”.

5. Structural – Besides inspecting the wood elements for chemical and biological attack, inspection for split, cracked, or bowing columns, sagging braces, and loss of any elements in the structure should be noted. It is very important to look for loose bolts in braces and column connectors. Any loose bolts should be tightened immediately. Evaluation should be done on the cause of loosened bolts. Particular attention should be paid to cracks through bolted joints. Fouling (plugging) of film

fills will add considerable weight to fill supports. Inspect for cracked or broken support members. If present, the severity of fill fouling must be checked immediately. Also the softening of the surface and the depth of penetration of a probe should be noted as an indication of strength. Modulus of OElasticity testing, of members removed from the tower, could also be done to determine the extent of deterioration but generally, deterioration is not uniform.

B. Touch – Feel on the surface of the lumber to see if the surface is fibrous or deteriorating.

C. Probe – The ease with which a probe penetrates heavier members and the depth of this penetration. Also the type fracture made on breaking out is used as an indication of the type of deterioration or its absence in the interior. In inspecting for internal decay, a probe such as a blunted ice pick or a screwdriver is useful. A firm pressure will cause the point of such an instrument to penetrate about a ¼ inch into sound wood. If internal decay is present, the probe will break though the sound wood and penetrate into the softer decayed area.

D. Reporting Method - Chart Figure 13.1 can be used in determining when to conduct an inspection.

If the assigned purpose of the inspection was simply to document the condition of the cooling tower, the “Cooling Tower Inspection Checklist” could be used to do so, and can be supplemented with whatever text documentation is deemed necessary. The documentation could show the size and length of each element requiring attention, as well as its location. Recommendations for immediate or short-term scheduled repairs may also be attached. Recommendations for longer term repairs, upgrades, or other recommendations from the inspector, may be attached as well. Priorities should be established considering factors such as safety, operation, immediate needs, etc. Replacement considerations need to include risk of exposure, availability or lead time for materials and outage schedule timing.

Section 5. Inspection of Fiber Reinforced Plastic (FRP) Structural Members of Cooling Towers

13.5 A cooling tower structure assembled from high quality, high performance FRP laminates, designed properly with adequate UV and weather protection, should give an owner long, low maintenance service. The principal concerns of composite structures that can affect the structure’s life are ultraviolet rays of the sun (UV), sag (creep), shear stress, connections, and freezing. One advantage to FRP structural components as compared to other building materials is that it normally will give significant warning before it reaches the point of failure. Warning signs such as visible cracking and cracking sounds are typical warning signs. If a member becomes over stressed due to excessive loads, the first indication will be excessive or accelerated deflection or creep of the over stressed member. FRP cooling towers should be checked at regular intervals so that each cell in the complex is inspected at least once a year in conjunction with a preventive maintenance program. Additional

inspections should also be made after high winds, seismic events, operational transients (temperature, chemistry, hydraulic), major mechanical events, etc. Also consult the manufacturer's recommendations.

A. Visual

UV Damage – Some degree of fading and chalking is to be expected after five to ten years of service. Damage from the effects of the sun's ultraviolet radiation can be identified by the presence of fiber blooming (exposed glass fibers) in areas subject to direct exposure to the sun. Fading and chalking are not indications of structural damage due to UV deterioration. However when untreated can lead to fiber blooming and fiber blooming can lead to some structural loss. Chalking, fiber blooming and damaged areas should be treated with Sherwin Williams Polane S or similar UV resistant coating to maintain the integrity of the FRP members.

Deflection and Deformation – The principal concern of deflected or deformed structural members is whether or not the deformity is causing excessive stress on the connections. If deflections or deformations in excess of those allowed by CTI ESG-151(02) are observed, the cause of the deformity should be determined. One indication of overloaded structure is if the bolts start to "plow" through the face of the FRP structure.

Structural Damage and Cracking – FRP members should be inspected for damage, cracking, or potential structural failure. The use of FRP bearing pads under high load columns can cause failures of the column bottom (particularly of cross flow tower pipe columns). The ends of exposed horizontal tie lines could be inspected to determine if any delamination is occurring.

Connections – Principal problems associated with connection points are stress cracking, bolt hole elongation, and loose hardware. Extra effort should be made to search for these problems in heavily loaded members of the structure. Refer to CTI ESG-151(02) for further information. Care should be taken when correcting loose bolting to avoid over-torquing per manufacturer beyond manufacturer's standard requirements.

Freeze Damage – Freeze damage can be identified by looking for cracking at the base of the structural member. If weep holes in hollow members are present, they should be checked to make sure that they are open for drainage.

Chemical Attack – Chemical attack, while highly unlikely, can be identified by the existence of localized fiber blooming or surface blisters. Placement of chemical lines within the cold water basin should not allow the chemicals direct contact with the FRP members.

B. Reporting Method – (Same as 13.4-D)

Section 6. Inspection of Reinforced Concrete Members of Cooling Towers

13.6 The structural condition assessment of concrete cooling towers is essential to identify conditions that represent safety and process concerns, determine root cause of the deterioration/damage and develop repair/protection recommendations. Mechanical and natural-draft cooling towers present unique damage/deterioration inherent to their type of construction and process/environmental exposure conditions. Therefore, condition assessments should be conducted by structural engineers who specialize in forensic evaluation of structures and have an understanding of the process occurring within cooling towers, especially since oftentimes the process becomes the driver for the deterioration and damage. Concrete mechanical-draft cooling towers and water distribution sections of natural-draft cooling towers are often precast concrete construction. The precast double tee elements for decks are similar to those found in precast parking garages. Certain cooling tower designs incorporate pre-stressed precast concrete process elements such as fill beams and louver panels of very slender cross section which are susceptible to deterioration and sudden failure. Other elements within cooling towers such as the basin and the veil in natural-draft cooling towers are cast-in-place construction. The exposure of the concrete to process water provides the ingredients necessary for several disintegration/deterioration mechanisms such as corrosion, freeze-thaw damage, sulfate attack and alkali-silica reactivity.

A. Field Investigation Approach

Most condition assessments of reinforced concrete cooling towers include a variety of investigation and testing techniques. Provided below are selected techniques that can be included as part of the assessment. The list of testing techniques provided below is not meant to be comprehensive. The testing scope for a particular assessment should be pertinent to the specific condition to be addressed. Testing and interpretation of results should be conducted by trained and qualified personnel.

Visual Survey - The purpose of a visual survey is to document concrete conditions such as cracking, delaminations, spalls, and readily visible structural displacements or distortion. Preparation of condition survey drawings and record photographs should be prepared to document observed conditions. When possible, condition survey drawings should include dimensions and locations of the observed distress. Drawings and photographs provide information that can be used to compare conditions of subsequent surveys with previous surveys.

Hammer Sounding - Hammer sounding of accessible concrete surfaces is useful to identify apparent signs of unsound concrete. Typically, surfaces impacted with a hammer exhibit either a sharp metallic ring or a dull hollow sound representing "sound" and "unsound" conditions, respectively. Hammer sounding is typically used to locate delaminations (partially detached cover concrete) associated

with corrosion of embedded steel reinforcement and its associated concrete deterioration. However, other conditions associated with shallow voids or unsound concrete such as poor concrete consolidation can be identified as well.

Rebound Hammer Testing - Rebound hammer testing provides an indication of relative surface hardness of concrete. A rebound hammer consists of a spring-loaded steel plunger which impacts the concrete surface with a known and reproducible force. Based on the rebound of the steel plunger as it impacts the concrete surface, the relative surface hardness can be determined. Even though rebound hammer manufacturers provide a correlation between the resulting rebound number and concrete compressive strength, the indicated compressive strength values should not be taken as the actual concrete strength. Additional testing and correlation are necessary to evaluate in-place strength of concrete.

Rebar Locator Survey - The rebar locator survey can be used to ascertain the presence, orientation and concrete cover of the as-built reinforcement. The as-built information obtained from the rebar locator survey can be compared with as-designed conditions from the design drawings. The rebar locator survey could also be useful to establish clear locations for concrete coring. There are different types of equipment available to conduct rebar locator surveys which include magnetic principle based devices (covermeters) and ground penetrating radar (GPR) sometimes referred to as short pulse radar (SPR). The specific equipment to use depends on the thickness of the concrete element, depth of the reinforcement to be located and the desired level of accuracy. Whenever possible, it is recommended that confirmatory exploratory openings be conducted to confirm/calibrate the results from the rebar locator survey.

Corrosion Survey - Determination of corrosion potential and rate is useful for assessment of corrosion of embedded reinforcement. Corrosion of embedded reinforcement is one the most widespread deterioration mechanisms in concrete cooling towers. Equipment for a corrosion potential survey consists of a voltmeter and a half-cell usually copper/copper sulfate or silver/silver chloride. ASTM C-876 provides criteria for assessing the probability of ongoing corrosion of steel in concrete.

Different proprietary testing equipment is available for corrosion rate measurements. Corrosion rate testing provides an indicator of the rate of corrosion deterioration utilizing the principle of linear polarization. The results are dependent on the specific type of proprietary testing equipment used. Both corrosion potential and rate testing are affected by the moisture levels in concrete as well as weather conditions.

Nondestructive Stress Wave Transmission Methods - Several proprietary testing instruments are available which rely on some form of stress wave transmission to assess the quality of the concrete material and the presence of

subsurface conditions such as poor consolidation (honeycombed concrete), voids, delaminations or internal cracking. Some of the stress wave transmission techniques include Ultrasonic Pulse Velocity, Impulse Response and Impact-Echo Testing. In principle, these non-destructive testing techniques involve “pitch and catch” of different forms of stress waves through concrete.

Exploratory Openings - Exploratory openings are used to expose conditions within concrete such as embedded elements (rebar, anchorages) or faults (cracking, delaminations, voids). Exploratory openings can provide “truth and verification” for certain non-destructive techniques. Proper surface repair techniques shall be utilized to repair the exploratory openings sample holes.

Sample Extraction - Concrete samples in the form of concrete cores, fragments or powder can be extracted for examination or testing. Concrete cores can be used for compressive strength testing, chloride content testing, petrographic examination or visual examination. Concrete powder obtained directly from the structure is used for determination of chloride content levels. Proper surface repair techniques shall be utilized to re-establish original surface contours.

B. Laboratory Testing Chloride Content Testing - One of the mechanisms associated with corrosion of reinforcing steel in concrete is chloride attack. Chloride ion concentrations can be measured from concrete powder samples obtained directly from the structure element or from concrete cores. Collection of powder samples from concrete cores allows for the extraction of powder samples at different depths so that a chloride concentration profile can be produced. A chloride profile is useful in determining the source or direction of penetration of chlorides. Chloride concentrations are very helpful to identify cause of observed corrosion, as well as evaluate the potential for on-going corrosion in the future.

Petrographic Examination - Petrographic analysis is the examination of concrete using methods and techniques derived from geology. Concrete petrography requires the careful examination of samples by highly-trained specialists. Typically, samples for petrographic analysis are obtained in the form of concrete cores. From the core samples, “thin sections” are prepared. The “thin section” samples are examined using stereo and petrographic microscopes and, if necessary, a scanning electron microscope. Petrographic analysis is useful to evaluate the overall quality of the concrete and identify the presence and extent of concrete deterioration such as freeze-thaw and chemical attack.

C. Structural Analysis

In certain cases, structural analysis to evaluate structural integrity and safety might be required. The analysis could be simple hand-calculations or a complex finite element model depending on the situation. Structural analysis should be performed to investigate overloading conditions from higher